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A CASE STUDY USING A DAYLIGHT SIMULIATION TOOL

Daniel C. Glaser
Light Foundry, LLC, Berkeley, CA
daniel@lightfoundryllc.com
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ABSTRACT

This paper presents a case study of a designer using a new daylight simulation tool for planning lighting systems. Discourse analysis codifies and interprets the designer's talk and gesture during an extended user study. It illustrates, in fine-grained detail, how a professional interacts with the software and author on a hypothetical design problem. Professional training is identified as both an enabling and disabling factor for use. .

INTRODUCTION

Understanding how users and organizations work with and adopt simulation tools has been of intense interest to the building performance community (Augenbroe 2001). It is recognized that building simulation is orchestrated by professionals from a variety of backgrounds each with their own capacities, requirements, and training. Survey research (Donn 1997; Mahdavi, Feurer et al. 2003) has established baseline practices as well as user-requirements for tools. Others take a more participatory approach by providing in-house support (McElroy, Elrick et al. 2003) (de Groot, Maassen et al. 2001). Nevertheless, there has been very little published on how building designers work with new simulation tools on a design problem. This is an important area to study since it can provide a scientific basis for answering long asked questions of what makes a simulation tool user-, designer-, or profession- “friendly”.

This paper illustrates an in-depth case study of how a designer uses a lighting design prototype (Glaser, Ubbelohde 2002). It relies on screen, voice, and gesture data recorded on a digital camcorder. About two hours of data were recorded for this test, resulting in many pages of transcripts. A small, but exemplary, portion is excerpted for this paper which identifies usability, learning, and professional adoption issues. In summary, this paper provides a methodology, through a case study, for understanding how designers actually work with new simulation tools.

METHOD

Conventions were adapted from conversation analysis for coding Brina’s user study (Table 1). First, time codes appear at the top and bottom (SS:SS and EE:EE) of each transcript. Utterances are numbered consecutively from the start of the analysis. A break in numbering occurs once (between lines 34 and 101) to signify about twelve minutes of the user study that were omitted from this paper. Each line is categorized into a segment code for cross referencing in the analysis and paper figures. The speaker is denoted as [D] for Dan, the person who is asking questions, and [B] for ‘Brina’, a pseudonym for the lighting designer.

Table 1 Transcript notation.

SS:SS Line # EE:EE	segment code	[speaker]	utterances

Segment codes are labeled as follows. Design interventions are denoted by nD_X, where n is the stage and x the step. The symbol nD is used to describe all steps in an intervention (e.g. 2D refers to $2D_1$, $2D_2$ and $2D_3$ if there are 3 steps). Conversation segments are coded by the symbols nC_{init} and nC_{end}. where n is the stage and init and end are their respective order sandwiching the design intervention.

Table 2 lists all the qualifiers that were used in coding the utterances of Brina’s user study.

Table 2 Symbols used in the utterance section.

?	rising intonation
‘	pause within a grammatical sentence
.	pause between grammatical sentences
<u>louder</u>	Emphasis: pitch and/or volume
°softer°	de-emphasize: pitch and/or volume
=	latching: grammatical sentences connected with a pause

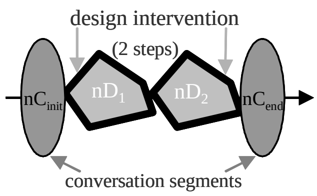

Figure 1 Timeline legend

[]   overlapping talk

A lighting designer study was conducted at the Pacific Energy Center in San Francisco, California. The participant "Brina" had 13 years of years of industry experience. She was shown some of the features of the software described in (Glaser, Ubbelohde 2002) and asked how she could incorporate them into a hypothetical design scenario. Specifically, Brina was asked how she would the tools for designing a lighting system for a pentagonal office with three windows (Figure 1).

Figure 2 shows the plot titled "AVERAGE" that Brina is engaged with during this portion of the user study. This spatial plot shows the average daylight distribution across the pentagonal room across most of the year (Jan 1 to Dec 26, 4am to 9pm) under clear sky conditions. This plot was constructed in two steps. The first by selecting a range of times of interest (Jan 1 to Dec 26, 4am to 9pm) in the temporal plot (not shown). This would show a series of pentagonal rooms and lighting performance graphs. The second step was to conflate all the plots into a single chart (Figure 2 right) which describes an average during daylit times. This resulting plot shows, on average, some parts of the room will receive very high amounts of illumination (about 1000 Lux), while others are relatively dim (in particular the east side of the room). This plot, while not representing a specific time, provides an overview of lighting performance by aggregating data throughout the day from January 1 to December 26th.

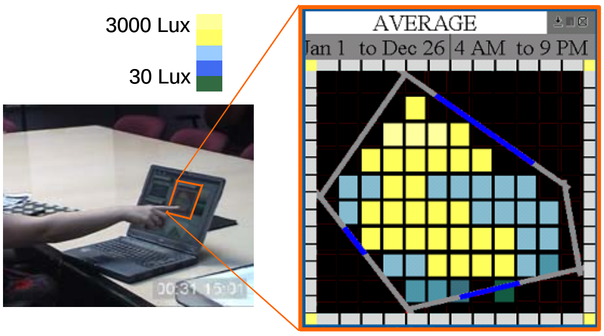

Figure 2 (left) A screen capture of the user study "Brina" and (right) close-up view of the panel she is pointing at.

Study Overview

The analysis identified two repeated phenomena during Brina's user study, a design intervention and conversation segment. Design interventions occurred when the user created a lighting system verbally or thorough gesture. Each design intervention consisted of a number of distinct steps. For example, one step was discussing a general lighting system while another wall sconces for balancing. Each is a distinct component of a lighting system, but together they form a complete design intervention. Design interventions are proceeded by and concluded with a conversation segment. These verbal segments serve as generators for and reflections about design interventions. Together design interventions and conversation segments form a stage.

Figure 3 is a timeline of the design interventions and conversation segments coded in the Brina user study.

Each stage is coded according to the symbols illustrated in Figure 3.

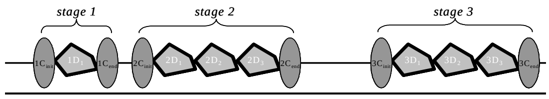

Figure 3 Timeline overview of the conversation (oval) and design (pentagonal) events during the Brina user study. Stages 1 and 2 were sequential, whereas there is a twelve minute gap between stages 2 and 3.

The timeline shows that there were three stages of activity. At stage 1 there was only one design intervention, while stages 2 and 3 had two. The gap between stages 2 and 3 shows a twelve minute omission in the transcript. This portion of the user study was unrelated to the design problem.

Stage 1- Initial Problem Framing

This stage marks Brina's introduction to and first attempt at solving the problem (Table 3, Figure 4). During the first introductory conversation segment ($1C_{init}$), Brina agrees to design an electric lighting system for the hypothetical room. She first described a design method for achieving a "good balance" (lines 6-7) in the space. Nevertheless in lines 8-10, she begins to read the graph ("we are looking kind of dim over there", referring to daylight availability), and starts a design consisting of a single sconce (1D, lines 8-10). Sconces are light fixtures that adjoin walls and wash light above them. At this point, she short-circuits the single step she took to reflect.

Table 3 Transcript of the first conversation segment and design intervention. Here the design question is framed and responded to.

30:53

1 $1C_{init}$ [D] would you use that in, actually, your design for, for, uh=

2	$1C_{init}$	[B]	=I [will]
3	$1C_{init}$	[D]	[the] electric lighting system and things like that
4	$1C_{init}$	[B]	=now that I have seen it, I will=
5	$1C_{init}$	[D]	=aha
6	$1C_{init}$	[B]	=uhm, there we are always trying to get a balance with
7	$1C_{init}$		that type of lighting, so even though you get a lot of
8	$1D_1$		daylight, in this pattern, and we are looking kind of
9	$1D_1$		dim over here so we want to get a wall sconce or
10	1D1		something happening,

31:16

In conversation segment $1C_{end}$ (Table 4), Brina, through invoking professional norms, questions the relevance of designing for daylight. She says that it is unrealistic to design for the sun since it has a high degree of variability (lines 12-18) and is still concerned with the "balance" (line 12) of electric light. This result was not surprising since it was consistent the division of labor in lighting design offices—namely that daylight is delegated to the architect to manage. She uses the utterances, "we are assuming" (line 13) and "there is this sort of general assumption" (lines 18-19) to reflect that it is not she, alone, who is making this assumption. Nevertheless, she reflects upon "lighting for when it is dark" as being "not a very good idea" (lines 19-21) and understands that this may not be realistic. Hence, Brina is able to critically reflect about her profession's beliefs.

Table 4 Transcript of a conversation segment of the 'Brina' user study justifying why she interrupted her previous design solution.

31:16

11	$1C_{end}$	[B]	uh- there, we are always trying to design for a good
12	$1C_{end}$		balance, uhm and and good work light, no matter what's
13	$1C_{end}$		happening with daylight, because we are assuming a
14	$1C_{end}$		cloudy day or
15	$1C_{end}$	[D]	ok, [aha]
16	$1C_{end}$	[B]	[or bad] circumstances ((short laughter))
17	$1C_{end}$	[D]	=ok [great]
18	$1C_{end}$	[B]	[or ev] evening circumstances- so ther there is this
19	$1C_{end}$		sort of general assumption that which is probably not a
20	$1C_{end}$		very good idea, that, you know, lighting is for when it is
21	$1C_{end}$		dark and=
22	$1C_{end}$	[D]	=aha
23	$1C_{end}$	[B]	when you don't have a lot of daylighto,

31:44

Stage 2- Revised Design

Immediately after completing the first stage, Brina develops a new solution (Table 5, Figure 5). She starts to gain confidence in the interface's representation of daylight ($2C_{init}$, lines 24-25). She uses it to describe a general lighting system that can be turned off ($2D_1$, lines 26-27). The invention of a general lighting system is important since its function is contingent upon daylight—differing from standard practice. She proceeds to add wall sconces again ($2D_2$, lines 27-28) to brighten areas of the room that do receive low amounts of sunlight, on average. Lines 29-30 also show an expansion of her definition of lighting quality to include the building occupant as part of the solution. Hence she develops a notion of occupant which can lead to both improved lighting quality and a more energy efficient solution. Nevertheless she has concerns about occupant comfort and believes sensors will remedy the situation (32-34). Brina is able to utilize the interface since her expertise in lighting design allows her to engage this "new" light source.

Table 5 Transcript of the second design intervention of the 'Brina' user study.

31:45

24	$2C_{init}$	[B]	so, uhm but I think, I think it would be a useful tool to
25	$2C_{init}$		know where the daylight is coming in,
26	$2D_1$		so that maybe, maybe there is a general lighting

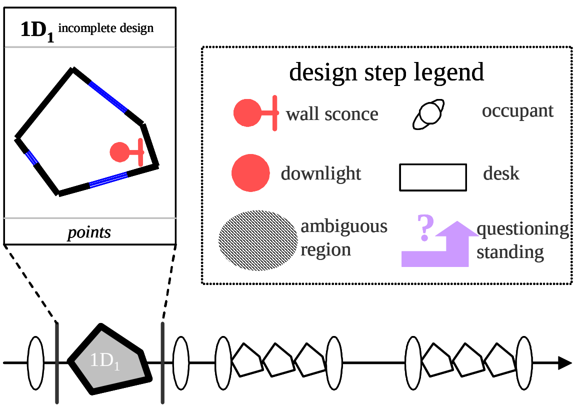

Figure 4 The first design intervention was interrupted after only a single wall sconce was specified.

27	$2D_{1-2}$		system that can be turned off and we add wall sconce
28	$2D_2$		over here and wall sconce over here
29	$2D_3$		then we have the person at the desk, be willing to get
30	$2D_3$		up, which is [the whole problem]
31	$2C_{end}$	[D]	[Right]
32	$2C_{end}$	[B]	=with those sensors, so that people don't have to get up
33	$2C_{end}$		from their desks to change the light,
34	$2C_{end}$	[D]	aha

32:13

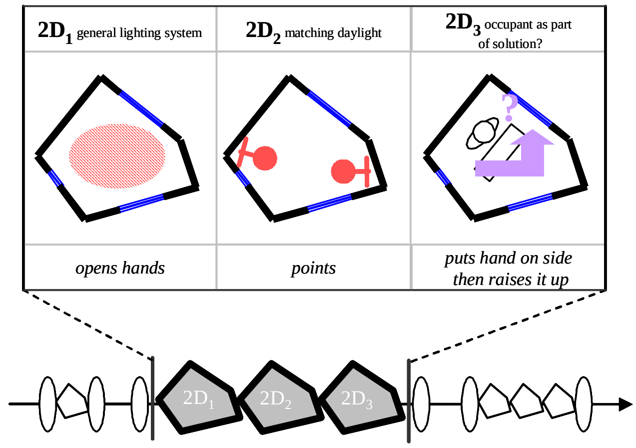

Figure 5. The second design intervention starts to reconcile daylight with the electric lighting system. Brina

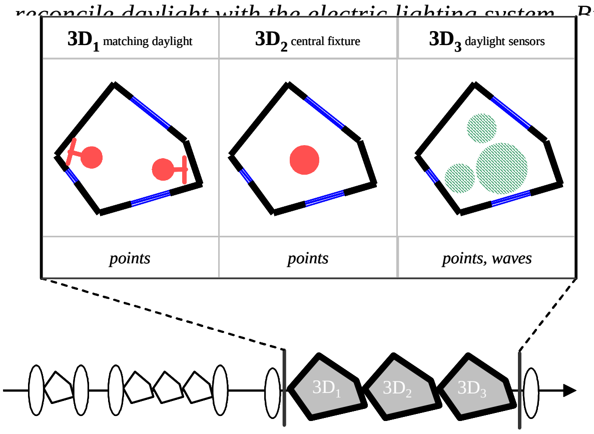

Figure 6 Excerpt of the third, and final, design intervention. Brina is content with her solution.

Stage 3- Revisiting Design Problem

About 12 minutes later in the user study, Brina suddenly revisits the design problem (Table 6, Figure 6). In $3C_{init}$, Brina discusses the necessity of adopting information that is pertinent to her job. She is able to quickly revise her solution (3D) to accommodate the concerns she had about the occupant in the second design intervention. Specifically she recommends daylight sensors to switch the lights (so that the occupant does not have to be bothered). Although this particular control strategy may not be favorable to all occupants (as noted in(Illuminating Engineering Society, Rea et al. 2000)), Brina is now satisfied with her solution ($3C_{end}$). It should be noted that sensor placement and controls are not a typical task for a lighting designer.

Table 6 Transcript of the third stage of the 'Brina' user study

44:03

101	$3C_{init}$	[B]	you have to figure out, you have to get enough
102	$3C_{init}$		information to do the job properly. You have to get sort of
103	$3C_{init}$		the least amount of information to do that job=
104	$3C_{init}$	[D]	ok
105	$3C_{init}$	[B]	to the best of your ability. So as soon as you understand
106	$3C_{init}$		where you're going, =
107	$3C_{init}$	[D]	[uh huh]
108	$3D_1$	[B]	[like] I now understand that this side of this room
109	$3D_1$		could be the wall sconce and this side of the room,=
110	$3D_1$	[D]	=ok.
111	$3D_1$		[uh huh.]
112	$3D_2$	[B]	[ok] and that, you know, if I put a fixture in
113	$3D_{2\text{-}3}$		the middle, and I give the daylight
114	$3D_3$		sensor here and there, near the, you know,
115	$3C_{end}$		ok, I've [got it]
116	$3C_{end}$	[D]	[uh huh]
117	$3C_{end}$	[B]	sort of solved in my mind, and
118	$3C_{end}$	[D]	[aha]
119	$3C_{end}$	[B]	[so I] can move onto the next [thing].
120	$3C_{end}$	[D]	[aha]

44:42

SUMMARY

There were three stages in Brina's user test each showing an increased mastery using the visualization tool. In the first stage she started to propose a solution that integrated both daylight and electric light, but interrupted herself due to the division of labor in practice. Nevertheless, she was able to critically reflect on these assumptions and starts a second stage of design work. In this stage, she proposes a solution that she has some reservations with. Over twelve minutes later, in the third stage, Brina revisits the problem and resolves it to her content.

From the perspective of building performance, Brina improved both the lighting quality and energy consumption in her proposed design. The lighting quality was improved due to her balancing daylight with electric light. Specifically, by designing two electric lighting systems (a general system, with wall sconces for highlighting) the occupant (or sensor) can chose to turn on or off one or both to make the lighting more even during daylight hours.

CONCLUSIONS

This paper presented a method for understanding how people interact with building simulation software. It illustrates how user interaction can be captured, codified, and analyzed using a video camera. In this case study, it illustrated how the "average" plot was initially illegible by the user due to professional biases. But within a period of minutes, this plot was employed by the designer to construct a lighting system that accounted for daylight. Although the user had little or no training in daylight, she was resourceful enough to combine the new daylight simulation tool with her existing experience and training in electric light to solve the problem.

This study also shows some of its shortcomings of the simulation tool. Namely since the designer talked about daylight autonomy and sensor performance, they should have direct simulation support for it.

To summarize, the lessons learned from this study are:

- A way of predicting user performance is through observing case studies. More research is needed in this area to validate usable building performance tools.
- Practitioners continually reference professional norms when designing. This has both positive and negative implications on performance.
- There is an interpretive aspect for reviewing user studies. Codifying data provides a necessary, but not sufficient, structure for analysis.

One area of future work relates to improving this notation with coding more user studies. We are currently examining data from three more user settings that use a newer version of the software (Figure 7). Initial results of examining collaborative design indicate that the linear structure presented in the 'Brina' case study can be augmented with branching. Another area of development is with establishing baseline quantitative metrics, such as time to complete a task, error rates, and design performance. Finally, more work has to be done to change real-world office perceptions that "lighting is for when it is dark" so that practices can fully embrace daylight simulation tools.

Figure 7: A screen capture of multiple groups of practitioners simultaneously using the software.

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